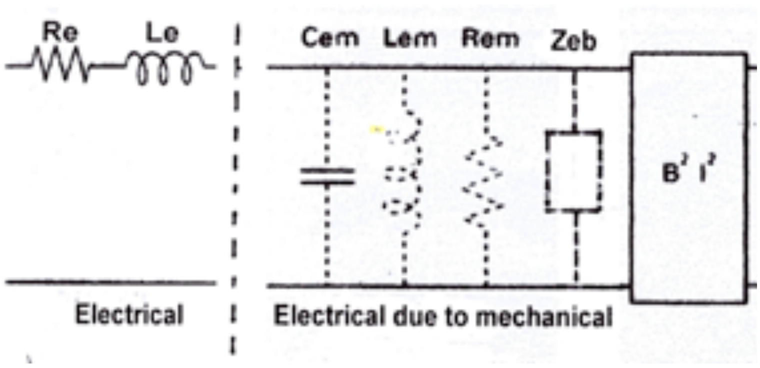
PLEASE NOTE THAT THIS CHAPTER IS CURRENTLY BEING REVISED IN VIEW OF OUR LATEST FINDINGS

## LOUDSPEAKER PARAMETERS

It is generally known, (but rarely admitted), that parametric measurements can be far from reliable. This issue was first raised by the Author in an article entitled ***'THE PARAMETER GAME'***, published in the Hi – Fi News. June 1996

In order to examine the causes of inconsistency, a passive electrical circuit was set up using real components of known values as shown below, This simulated that of a typical loudspeaker as 'seen' by the amplifier. **(Fig 18).** Tests were made by both direct measurement and by computer derivations using a range of stimulation types and levels. The results were substantially consistent in all tests.

**Fig 18**




**Re =5.483ohms,**
**Le = 137.4uH,**
**Cem = 375mfd,**
**Lem = 20mH,**
**Rem =14.5 ohms.**
**Zb= infinite, (driver in free air).**

| | Fo (Hz). | Res | Rem | Qms | Qes | Qts |
|---|---|---|---|---|---|---|
| **Direct measurement** | **58** | **6.2** | **14.5** | **2.02** | **0.95** | **0.65** |
| **Computer derived.** | **58.68** | **6.8** | **15.2** | **2.10** | **0.98** | **0.67** |

**Check: Fo calculated from given values of Cem and Lem: 58.14Hz**

The differences in the value of Res and Rem in each case are due to Res being a direct measure of the voice coil resistance and a computer derived a value for motional impedance (omitting the fact that there was no motion).
**Fig 19** below, shows the plot of the above 'idealised' circuit. The key frequencies are indicated as follows:

**Mkr1=Fo. Mkr2= Rem. Mkrs 3 and 4= Bandwidth determining 'Qm'**

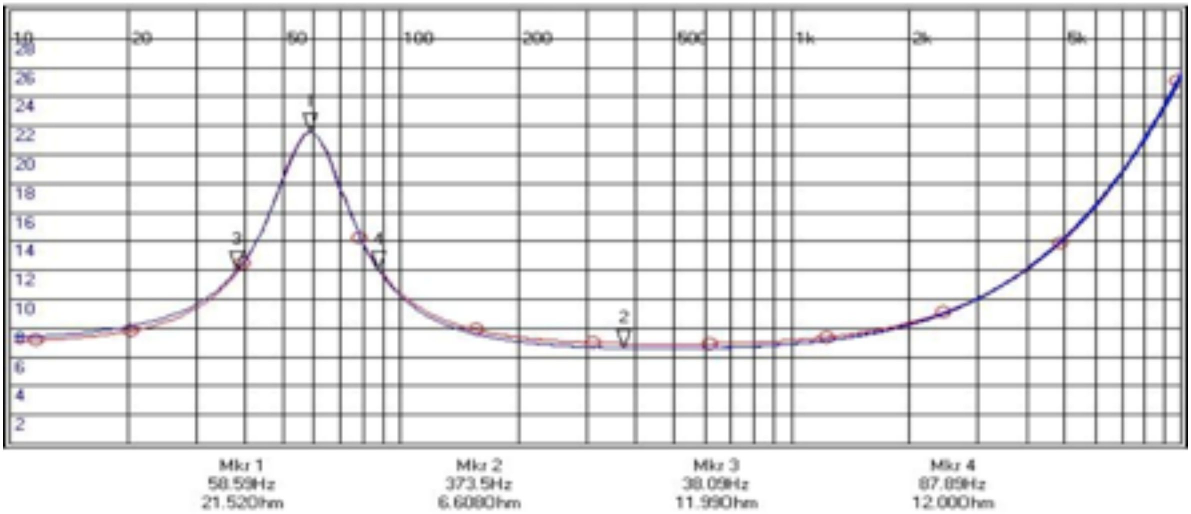



**Fig 19**

The forgoing demonstrates that apparent inconsistencies are not, in practice, due to acquisition error but due to the effective electrical impedance characteristics of an actual loudspeaker as 'seen' by the amplifier varying with the test conditions. The principle sources of error are the force/displacement non-linearities in both the motor system and the suspension compliance.

The impedance at frequencies around ***Fs***, is given by

$$Z = [(2\pi f.Lem - 1/2\pi f.Cem)^2 - Rem^2]^{1/2}$$

But from **Table 1, 'Lem'**, **'Cem'** and **'Rem'** are inversely proportional to **'$B^2L^2$'** and, therefore their values are subject to the non-linearity of the driving force.

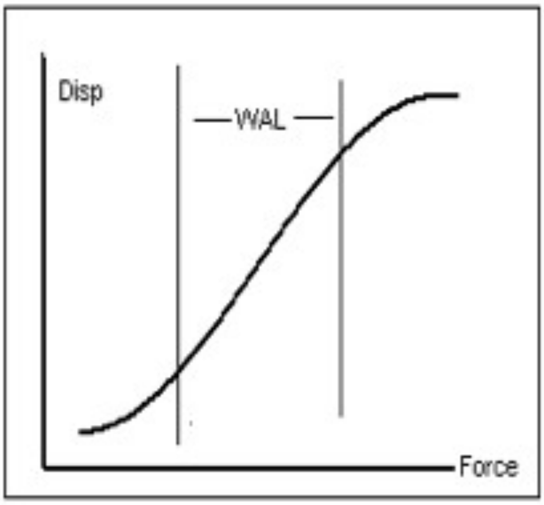
***Lem*** and ***Rem***, are derived from the compliance and internal friction of elastomeric materials. These can vary not only with time and temperature but they also exhibit a non-linear force/displacement characteristic resulting in a variation of resonant frequency with cone amplitude.

Due to the combined effects of these non-linearities, the variation of loudspeaker parameters with cone displacement can be quite substantial. Plotting these variables against voice coil current produces ***'S'*** curves, which may or may not have a common centre but will result in a composite curve of the form, ***Fig: 20***.

The plot shows a central area that is reasonably linear and a flattening towards each end. The central area will be referred to as the **W**indow of **A**cceptable **L**inearity, **(WAL).**

It would, therefore seem logical for all parametric tests to be made within the linear limits of this window which would also be more representative of real programme levels. Yet, remarkably, the unquestioned traditional approach is to test at low levels where it is claImed the distortion is minimal. It clearly is not!

**Fig 20**




**TEST PROCEDURES for IMPROVED ACCURACY**

**Direct Testing of Parameters.**

The traditional way of direct testing is the 'constant current' method where a relatively high resistor is connected in series between the signal generator and the loudspeaker and the parameters derived from the voltage across the voice coil. This not only severely limits the actual voltage across the coil resulting the errors described above but also limits the normal damping control around the resonant frequency and displacement

A preferred method is to use a 'constant voltage' approach using a high quality A.C. milliameter in series between the signal generator and the loudspeaker thereby deriving the impedance parameters from the measured current. This ensures that the performance of the drive unit can be seen to be operating under normal working conditions at every stage. It is also less complicated.

The procedure is to set the generator to some very low frequency well below the expected loudspeaker resonance. Advance the generator voltage to a point just below audible distortion. Adjust the frequency to find the point of minimum current. Observe any changes in this frequency by increasing or decreasing the voltage. Find the voltage range over which the frequency of the current minimum is substantially constant. This is the range maximum linearity. To simplify calculations, finely tune the voltage to 'round-up' the current value to two significant figures. Record the values of the applied voltage, (Va), the current' (Imin) and the frequency, (Fs).

Keeping the voltage constant adjust the frequency upwards to find and record the current maximum (Imax).

**Ro = Imax/Imin**

**Re = V/Imax**

**Find the frequencies above and below 'Fs' where I = $(Imax.Imin)^{1/2}$ (Ensure that Xmax is not exceeded at fl).**

**Then: Qm = Fs. $Ro^{1/2}$/fh-fl.**

**Imn = V / Rdc**

**Imx = V / Imn**

**$Rmx = V / Imn$**

**Fh and Fl at $(Rmx \times Rdc)^{1/2} = (Imx \times Imn)^{1/2}$**

**$Qm = Fs\ ro^{1/2} / (Fh - Fl)$**

**$Qe = Qm . Rmn / (Rmx - Rdc)$**

**$Qt = Qm\ Qe / (Qm + Qe)$**

**$Vas = Vb [\{Fb / Fs\}^2 - 1]$. (Note: Due to the problems already mentioned, this may not be accurate). The most reliable method is for Mms to be weighed at the manufacturing stage and Vas calculated.**

**Then: $Vas = d.c.A^2/(2\pi Fs)^2.Mms$**

**$Mms = Ma / [(Fs/Fa)^2 - 1]$ (Not recommended)**

**$Efficiency = 7.6 \times Fs^3 \times Vas / Qe \times 10^7$**

**SPL = Sensitivity in dB = 112 + 10 log (efficiency)**

This approach does require some experienced judgment and the ability to manage basic algebraic operations. It is also time consuming.

**Computer Derivation of Parameters.**

Although parameter testing by computer offers a wide range of test options, including varieties of stimuli and levels, it is evident from the foregoing that these may give very differing results. Generally, the tests are made under semi-constant current conditions and the results derived and processed from the voltage across the voice coil. Probably, the most accurate results can be derived from a frequency sweep sometimes referred to as 'chirp' but if this is too fast it can be difficult to determine either the shape or level of the stimulus waveform as it passes through the resonant frequency.

The plots below, **(Fig: 21)**, show the effects of taken at three cone displacement levels. The green plot is correctly centred within the WAL. The input levels of the red and blue plots are below and above the WAL respectively. Both show a higher value of Fs indicating the effects of the regions of higher suspension stiffness. The blue plot has a sharper but lower peak due to the coil moving partially outside the linear limits of the magnetic field resulting in reduced damping and efficiency. It should also be noted that, although Fs may be well inside the **WAL**, the displacement at the lower bandwidth frequency might not be so. It should also be noted that any deformation of the impedance curve would be ignored by a 'best fit' curve resulting in a further source of error.

From the experience gained by direct testing, these problems can be largely resolved by the use of a slow sweep time – say 3 – 4 seconds so that the instantaneous voltage level at the resonance can be adjusted and an experienced person can observe any anomalies that may occur in the behaviour of the loudspeaker. This method will produce a 'fuzzy' graph which will be averaged, with reasonable accuracy, by the 'best- fit' curve. **(FIGS 22-23)**

It is worth noting the smooth symmetry of the curves achieved by this method until the minimum current value coincides with the lowest frequency.

**Fig 21**

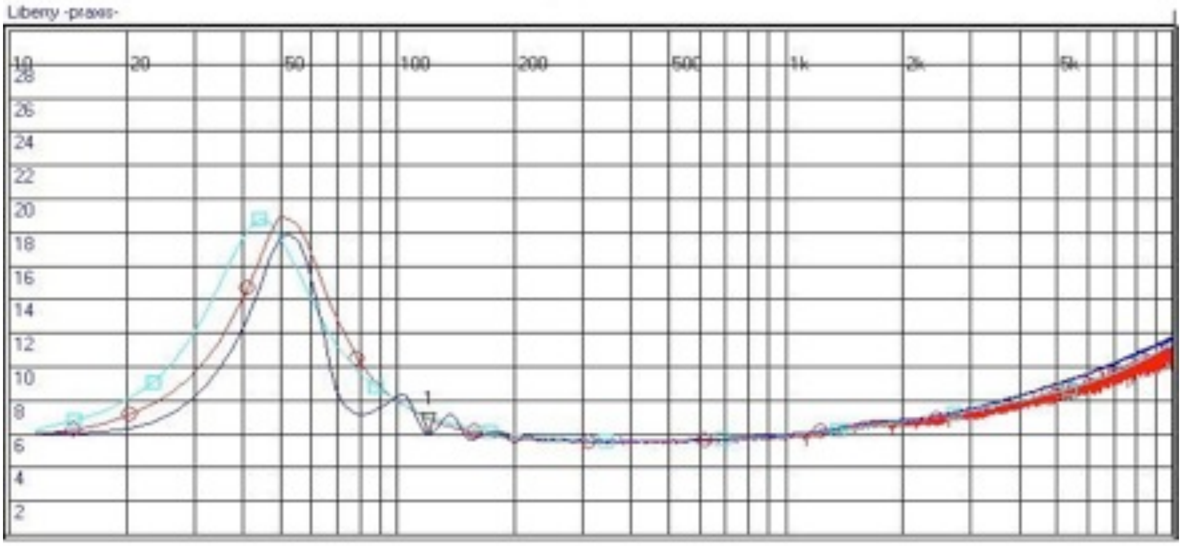



**Fig 22**

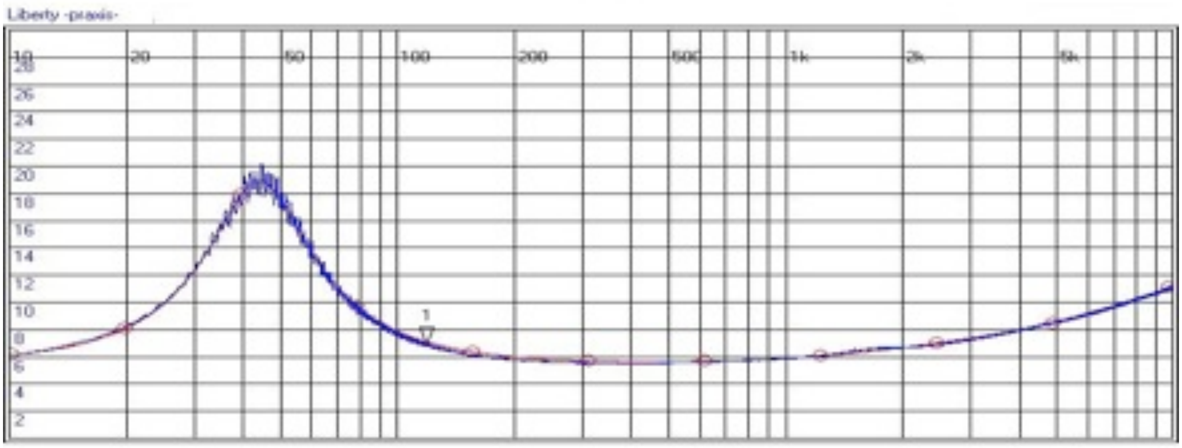



**Fig 23**